

THE PASTEURIZATION AND STERILIZATION OF MILK.

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Of all the food and drinks of man there is perhaps none which is more important than perfectly pure, clean, and healthy milk, and to secure it should be the subject of earnest care. The fact is well known that milk undergoes a number of chemical changes in its constituents some hours after milking. It becomes sour, owing to the decomposition of the milk sugar, the casein separates, and finally putrefactive decomposition begins. These changes are induced by the presence in milk of bacteria, which for the most part do not generate diseases, but which may be, and often are, accompanied by bacteria capable of causing disease that obtain access to the milk from the body of the animal, from the air, from the water that was used to wash the cans, from the hands, clothing, and person of the milker, and the like. Even when collected with precaution, the careless distribution of milk may result in its contamination with disease-producing bacteria.

The responsibility of milk for the distribution of a large amount of tuberculosis is at present more thoroughly appreciated than heretofore. To milk is also attributed the spread of typhoid fever, cholera, diphtheria, and other diseases, not to mention the many troubles peculiar to children that are to be traced directly to an impure milk supply. The latter are especially frequent in the crowded tenement districts of cities, where, through ignorance and lack of cleanliness, young children are surrounded by the worst possible conditions.

It is safe to assume that most of the ordinary bacteria found in milk gain access to it from the dirt of the udder, or some other portion of the animal, and when we remember that the feces are largely undigested food which is filled with an enormous number of bacteria, it is easy to see how easily milk becomes contaminated. The character of the bacteria in milk is also influenced by the straw used for littering, depending upon whether this is fresh and often changed, or whether it is already fermented and only occasionally changed. The dust from the earth and stalls will naturally also make a great difference in the purity of milk.

An idea of the amount of dirt and bacteria in milk can be obtained from the following figures: Renk found an average of 0.015 gram of feces in 1 liter of the milk sold in Halle, Germany; in that of Berlin, 0.010 gram to the liter, and of Munich, 0.009 gram to the liter (0.1386 grain to the quart). The maximum contamination in the milk in Halle

was 0.3625 gram of fæces to the liter. A good idea of the purity of milk may be had by ascertaining the number of bacteria it contains. This number has been found to vary from 10,000 to 100,000 per cubic centimeter immediately after milking, and increases enormously after standing for a few hours at the normal temperature. The first portion of the milking contains the largest number of bacteria per cubic centimeter, the last portion often none at all. If kept on ice the germs do not multiply. The bacteria which produce lactic acid and those which produce butyric acid are most common. The latter, together with certain spore-bearing bacilli present in the dust of the air, are the most difficult to contend against. It is apparent, of course, that some of this contamination can not be avoided.

The importance of a method or methods of freeing milk from these minute forms of life which cause so much damage, or of rendering them harmless, is evident. Several methods have been adopted to secure this end. The three most important are the use of chemicals, pasteurization, and sterilization, all being employed with the view of destroying the germs without injuring the properties, value, and healthfulness of the milk.

PRESERVATION WITH CHEMICALS.

Bicarbonate of soda is often used for this purpose; but, though this will neutralize the acidity, it rather favors than retards the increase of bacteria. Boric and salicylic acid are of some use in this connection, but both have been found to be injurious to health, even in small doses, if taken continuously. These and other chemical means are therefore neither satisfactory nor advisable.

The cooling of milk is well understood, but the most advantageous method of preserving it is by pasteurization or sterilization. In pasteurization the milk is warmed to 65° to 70° C. (155° to 160° F.), a temperature sufficiently high to kill the ordinary bacteria and pathogenic germs. There are a few germs, however, which can only be destroyed by heating the milk to the boiling point, the temperature of complete sterilization, and to these we will again refer under the head of sterilization.

PASTEURIZATION OF MILK FOR CHILDREN.

Dr. Koplik says, in an article to which we will again have occasion to refer, that in his experience in the city of New York he has seen children flourish amidst the most unfavorable surroundings when their food and milk supply was derived from his dispensary, where it was thoroughly pasteurized under proper conditions, while in the same districts other children which were left to the carelessness of the mother were sick and puny.

In addition to pasteurization, milk may be specially adapted for feeding to children and invalids by the addition of albuminoids and milk sugar. This makes it more nutritious and constitutes the so-called rec-

tified milk. The simple pasteurization of milk is useful, provided the milk is immediately cooled and used within twenty-four hours. If not afterwards cooled the pasteurization seems to increase the liability to fermentation. In thorough sterilization the danger to be avoided is the coagulation of the albuminoids or burning of the milk. Some authorities claim that the sterilization makes the milk too indigestible, while others claim that the digestibility is not affected, provided the sterilization is properly conducted and the milk is thoroughly stirred during the process. The latter process requires more care than the former.

Pasteurization can be easily carried on by any housewife. A simple and easy method is the one described in a circular issued by this Bureau, and which is here again printed:

The simplest plan is to take a tin pail and invert a perforated tin pie plate in the bottom, or have made for it a removable false bottom perforated with holes and having legs half an inch high, to allow circulation of the water. The milk bottle is set on this false bottom, and suffi-

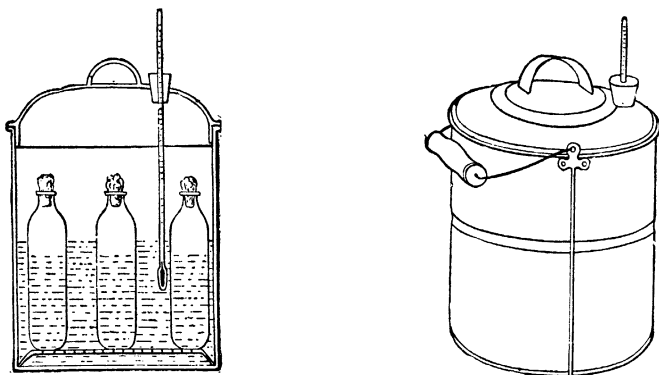


FIG. 52.—Sterilizing apparatus used in the Bureau of Animal Industry.

cient water is put into the pail to reach the level of the surface of the milk in the bottle. A hole may be punched in the cover of the pail, a cork inserted, and a chemical thermometer put through the cork, so that the bulb dips into the water. The temperature can thus be watched without removing the cover. If preferred, an ordinary dairy thermometer may be used, and the temperature tested from time to time by removing the lid. This is very easily arranged, and is just as satisfactory as the patented apparatus sold for the same purpose. The accompanying illustrations show the form of apparatus described (fig. 52).

PREPARATION OF MILK FOR INFANTS AND INVALIDS.

In the New York Medical Journal, February 4, 1893, Dr. Koplik describes the method used by him for several years in the Good Samaritan Dispensary in New York for the preparation of infants' food. The milk supply is derived from a reliable leading dairy and delivered in refrigerator tubs. This is a point of special importance to which we

will again refer. After many experiments and a comparison of results obtained by others, Dr. Koplik has found the most satisfactory temperature for the sterilization to be 85° to 90° C. At this temperature there is a slight deposit of casein upon the sides of the bottle. Above 90° C.

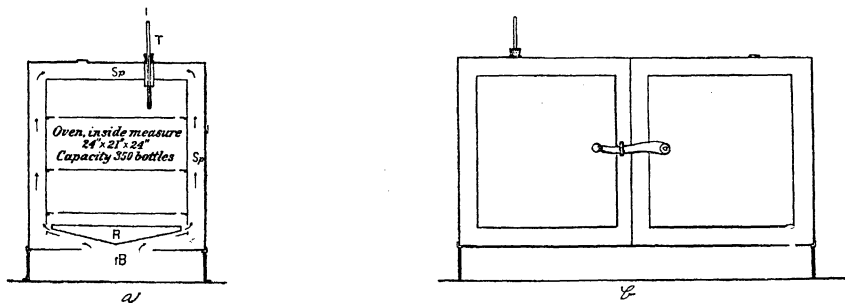


FIG. 53.—The Koch oven—interior and exterior views.

the milk presents a boiled appearance and flavor, and the butter rises and floats on the top. In the plan adopted by Dr. Koplik, bottles of different sizes are used, 2 and 4 to 5 ounces, just sufficient for one nursing, so that the return of the bottle insures a thorough steriliza-

tion of the sample for a repeated dose. The bottles are first filled with a saturated solution of soda and allowed to soak for twelve hours, and then thoroughly washed with a brush, both outside and inside, rinsed with pure water, and allowed to drain and dry.

After this they are heated in a Koch oven (fig. 53) to a temperature of 160° to 170° C. for forty minutes. They are then allowed to cool and are ready for filling with milk. The apparatus for sterilization is made of stout block tin and divided into five compartments and a steam box. The compartments are furnished with perforated bottoms and fit one on top of the other, forming a compact column (fig. 54) through which the steam can permeate. Each

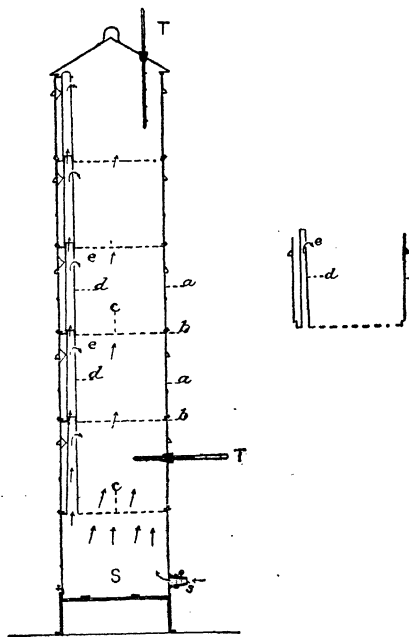


FIG. 54.—Koplik's pasteurizer.

compartment will hold fifty large-sized bottles. A thermometer passes through the cover of the top compartment and dips into the milk, so that the temperature can be noted. A stout tin pipe runs the whole

length of the sterilizer and dips into the top of each compartment, in order to fill the compartment uniformly with steam. The bottles, filled with the desired quantity, are placed uncorked in each compartment and covered with a cloth of clean flannel. When the milk has reached a temperature of 85° C. the process is continued for half an hour. The bottles are then taken out and rapidly corked with sterile rubber corks.¹ The whole process is completed in an hour. The milk used is always carefully examined. It must have 12 to 14 per cent of cream, and when boiled should not coagulate. The coagulation indicates the beginning of fermentative changes. Sometimes milk which tastes sweet will turn almost solid on boiling, showing that advanced changes have taken place. The slight acidity which would admit of detection only by chemical means would be apparent on boiling by the curdling of the milk. A little experience will enable one to detect the difference between the coagulation due to acidity and that ordinarily present after sterilization of good milk. The milk is bottled from large glass percolating funnels, thus requiring very little handling. For sick infants the diluent for the milk, a 4 per cent solution of milk sugar, is furnished. Limewater, as supplied by the drug stores, may also be used. If barley water is used as a diluent, it should be very carefully prepared and the milk diluted by an expert. Leaving the barley water to be prepared by the ignorant, or using barley water made from poor material, leaves open too many chances for infection. During two seasons Dr. Koplik states that 1,268 children were supplied with the milk from his laboratory; 729 infants received the milk for only one or two days, while 539 received it for from one week to five months. About 400 of the latter he thinks were really benefited by the use of the milk.

This apparatus could be adapted for sterilizing milk in larger bottles and in greater quantity.

In Boston and New York private laboratories have been established for the purpose of rectifying milk, as it is called. These laboratories supply pasteurized milk on physicians' certificates, or milk to which has been added peptone, sugar, or other material as the physician may direct. The bottles, about 8 ounces in capacity, after being thoroughly cleansed, are plugged with cotton and then sterilized. They are then filled with the milk, pasteurized directly with dry steam in a rectangular box especially arranged for the purpose. After pasteurization the bottles are packed in wooden cases lined with ice, so that the milk can be kept cool and shipped to any desired spot. This method is similar to the one recommended by the Bureau, and can also be readily conducted by any housewife, either with the use of the vessel described or an Arnold steamer.

¹The corks are of black rubber, and are sterilized by boiling for an hour in the solution of soda, rinsing with water, and sterilizing with steam. When the corks become brittle they are rejected.

Many different forms of apparatus for pasteurization in stoppered bottles have been recommended in Europe, the simplest being the use of beer bottles with the ordinary patent stoppers.

The sterilization or pasteurization of milk in bulk is a matter of great importance, to which much attention has been paid abroad, but comparatively little in this country. A pasteurizing apparatus invented by Professor Fjord and used in all creameries in Denmark is described here (fig. 55).

A copper cylinder, covered with tin, is fitted steam tight into a larger vessel, made of copper or galvanized iron and covered with wood to retard cooling. The steam is introduced through the opening at *g* and passes out through *d d*. The milk or cream enters at *c* and passes out at *e*. This exit tube has a pocket into which a thermometer can be placed, so that the temperature can be controlled. The agitator, *a*, is of wood or metal, connected to a shaft, so that it will make about 150 revolutions per minute. The temperature used varies between 160° and 180° F. In some dairies in Denmark the sweet milk is pasteurized. In others the cream is sterilized and then cooled before being set aside to ferment. In nearly all cases the skimmed milk which was returned from the cooperative dairies to the producers was sterilized as it left the separators. In this way it would keep better, and when fed to calves all danger from infection with tuberculosis would be avoided. If sweet milk is sterilized, the separator skims it cleaner, but the sterilization very slightly diminishes the amount of butter, as a little more fat is left in the buttermilk. On the other hand, the sterilization of cream before churning will give a more uniform and better butter.

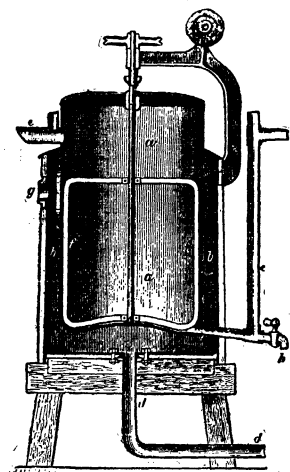


FIG. 55.—Fjord's pasteurizing apparatus.

In the city of Posen,¹ Germany, a satisfactory method of supplying sterilized milk in quantity and cheaply has been adopted. After washing the teats of the cows thoroughly, the animals are milked with care, the milk collected in metal vessels, centrifugalized twice, and placed in flasks of 100 to 400 grams capacity, respectively. Soxhlet's patent stoppers are used.² The milk is then placed in metal casks heated by steam, the steam having a temperature of 104° C. in winter and 104½°

¹Hesse. Zeit. f. Hygiene, vol. 13, Hft. 1, p. 42.

²Soxhlet's patent stopper consists of a rubber cap which fits over the top of the bottle and acts as a ventilator to relieve the inside pressure of the bottle, and prevents the outside air from entering the flasks. It is held in place by a metal cap which prevents it from slipping. The bottles are heated for thirty-five minutes in a water bath. After the flask is once opened it should never be used again without resterilization, as the removal of pressure loosens the cap. (Fig. 78, *a*, p. 355.)

in summer. A higher temperature causes coagulation of the casein and makes the milk indigestible for children.

For sterilizing milk, in 1892, Oekonomie-Rath Grob, in Berlin, used flasks with patent beer stoppers, and this has since been recommended by others.

In Dresden, milk is sterilized in large quantity in the following manner: The firm draws its supply from a large estate in the neighborhood. The animals that supply the milk have only dry fodder, and every attention is paid to the cleanliness of the stalls, apparatus, and hands of the milkers. The milk is cooled to a temperature of 10° to 12° C., and reaches the creamery two or three hours after its collection. It is first freed from dirt by a specially constructed centrifugal machine, then warmed to 65° C. and collected in a vessel from which it is finally transferred to sterilized flasks with patent stoppers, holding one-third liter. These flasks are then placed in a sterilizing case and submitted to the action of steam for one and three-quarters hours. They are then removed and quickly cooled to prevent burning. The milk prepared in this way can be readily used. During a year, out of 70,000 liter flasks that were sterilized and subsequently placed in an incubator for the purpose of testing the sterilization, only $63\frac{1}{2}$ were found spoiled.

As the milk would seldom be subjected to this temperature (that of an incubator), but would generally be used within a day or two after sterilization, it is not likely that a flask of spoiled milk would be obtained.

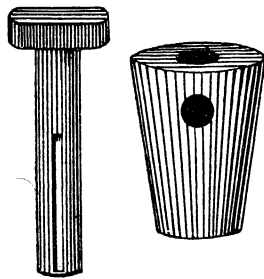


FIG. 56.—German sterilizer stopper.

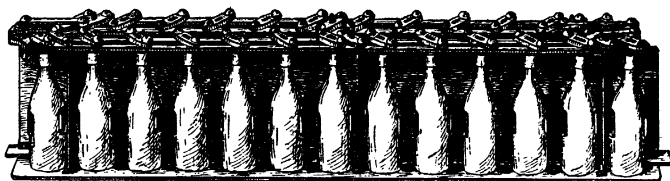


FIG. 57.—German sterilizing flasks.

One of the principal points to be desired in sterilizing milk is that it can be done in flasks or cans that in turn may be transported for a considerable distance without danger of the milk becoming contaminated. In order that this may be the case, the milk should be sterilized or pasteurized in flasks that admit of being tightly closed. An arrangement for this purpose, which is used in Germany and very highly recommended, consists of a rubber stopper with a central hole and side opening, and a nail-shaped glass rod with a side slit, as indicated in figure 56, and the whole sterilized in a closed box, as shown in figures 57 and 58.

After heating for three-quarters of an hour, the flasks are opened by means of the parallelogram crank, so as to relieve the pressure, and then closed. After heating again, the flasks are carefully removed and the glass stopper forced into the cork, so as to entirely close the bottles. The taste of the milk is not at all changed, and side by side with fresh milk it is impossible to tell the difference.

Pasteurization in the household, whether according to Soxhlet or the Bureau, is open to certain objections. In the first place, considerable time is required for keeping the vessels clean, which is one of the essentials, and this should be done by someone who appreciates the

importance of the process. It requires more time than a housewife could conveniently afford, and if left to a servant, the probability is that the importance of the process will not be appreciated, and may consequently be carelessly carried out, or even, after a while, be entirely neglected. For this reason it would be better to have the milk reliably sterilized in bulk and so distributed. This should be done under the direct control of someone who understands the purport and importance of sterilization and can make the necessary examinations of the milk, not only

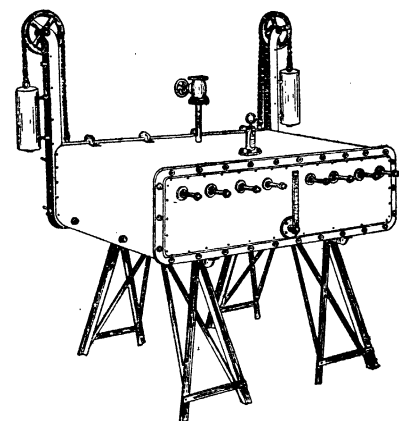


FIG. 58.—German sterilizer.

as to the proper fat contents, purity, etc., but also as to its freedom from germs after sterilization.

PASTEURIZATION OF MILK IN BULK, IN SMALL FLASKS OR CANS, IN AMERICA.

In addition to the preparation of milk for infant food as already described, a beneficent work has been undertaken in New York by Mr. I. Straus, for the purpose of supplying milk to the poor. The milk is prepared in a temporary laboratory on Third street, and is distributed in bottles from a number of different booths in the city. The milk in the cans is obtained from the Appleberg Hygienic Milk Company, of Dutchess County, N. Y. In the plant of Mr. Straus on Third street the process of sterilization is similar to that described above, but it is here repeated. The bottles, of tough glass, 6, 8, and 18 ounces capacity, are first boiled in borax water, thoroughly rinsed, and then sterilized in large Koch ovens. After sterilization they are filled with the milk and placed in copper holders (fig. 59). These are then placed in the sterilizers, which are the ordinary kitchen stove boilers (fig. 60). The boilers are filled with water, which can be heated either by steam or by a gas flame under the boiler. The cases are filled with water up to the

shoulder of the bottle. The water is heated and the bottles then placed in the boilers and allowed to remain for half an hour. At the end of this time the lid is carefully raised and gradually pushed around, so as to expose the mouths of only a few bottles at a time, and these are then quickly corked with solid black rubber stoppers which have been previously sterilized by boiling in borax or soda solution. The bottles are then taken out, cooled on ice, and distributed. Instead of these boilers for sterilization, there is sometimes used a large oven with water bottom, which is heated by steam, and the bottles are placed on shelves above, so that they do not come directly in contact with the steam. For dilution filtered water is used, and for further preparation barley water or limewater.

The process is under the supervision of two physicians, who examine the milk used and see that proper precautions are adopted. The for-

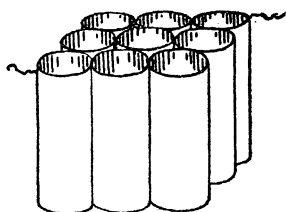


FIG. 59.—Copper holders used in Straus's plant.

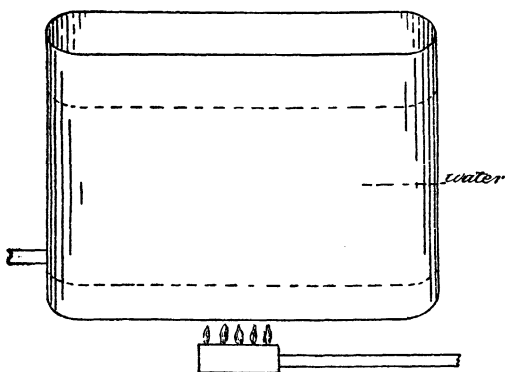


FIG. 60.—Copper boiler used in Straus's plant.

mulæ used for diluting the milk, as taken from the printed slip of the company, are as follows:

Formula 1.

| | | |
|---------------------------|----------|---------------|
| Sugar of milk..... | ounces.. | 12 |
| Limewater..... | pint.. | $\frac{1}{2}$ |
| Filtered water up to..... | gallon.. | 1 |
| Milk | do.... | 1 |

Formula 2.

| | | |
|--------------------|----------|---------------|
| Milk..... | gallon.. | 1 |
| Barley water | do.... | 1 |
| White sugar..... | ounces.. | 10 |
| Table salt..... | do.... | $\frac{1}{2}$ |

After being thoroughly mixed, the diluted milk is drawn into bottles, pasteurized as above, and sold for 1 cent per 6-ounce bottle. The bottles are returned and, after thorough cleansing, used again.

The milk is obtained from cows which have been inspected and pronounced free from disease. The prices at which this milk is sold are

not intended to bring any profit, but serve to partly defray the expenses of preparation.

Prices.—Raw milk, 4 cents a quart, 2 cents a pint, 1 cent a glass; pure milk, sterilized, 1 quart in four 8-ounce bottles, 5 cents; pure milk, 1 quart in two 16-ounce bottles, 2 cents; diluted sterilized milk (6-ounce bottles), 5 cents.

Deposit required on bottles.—Eight-ounce bottles, 3 cents each; 6-ounce bottles, 3 cents each; 16-ounce bottles, 5 cents each.

The prepared milk is guaranteed for twenty-four hours. It will, of course, keep longer, but this is the length of time that may be safely allowed, when the milk is given into so many different hands.

The principal plant for the pasteurization of milk in large quantity and in bulk is conducted at Pawling, Dutchess County, N. Y., by the Appleberg Hygienic Milk Company.

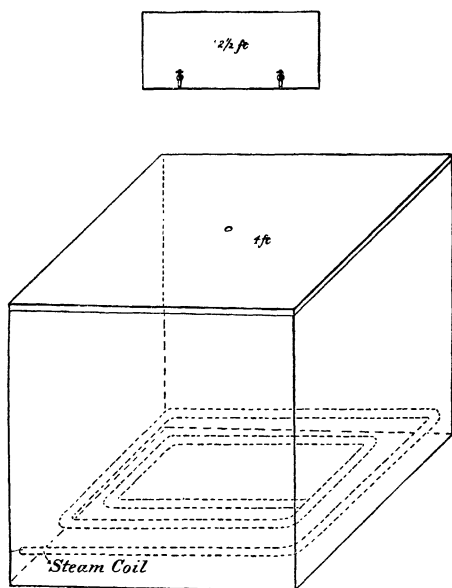


FIG. 61.—Appleberg's sterilizing box.

Pawling is situated near the center of one of the richest dairy counties of the State, so that the supply of milk is the best obtainable. When the milk is received at the factory any mechanical impurity is removed by straining and the whole is then aerated and cooled.

The apparatus for pasteurization (fig. 61) is patented. It consists of a wooden box about 4 feet square, with a hinged lid, and inside of the box is a coil of iron pipe to supply the heat. The milk is placed in rectangular tin boxes of a capacity of 40 quarts, covered with a perforated tin lid to permit the insertion of a thermometer by which to regulate the temperature. These

rectangular boxes closely fit inside the coil. The box is then closed and the steam turned on for twenty to thirty minutes, depending upon the milk and the season of the year. During the process the milk is kept thoroughly stirred. The temperature used varies from 160° to 180° F. The milk so pasteurized is then drawn while hot into the ordinary sterilized milk jars, or fruit jars with a flat top. Instead of a rubber washer, one of special paper is used. The jars are filled with hot milk and then set in troughs of ice water to cool. The contraction of the milk upon cooling creates a vacuum in the jars, which are thus hermetically sealed by the outside air pressure. In addition to the bottled milk, this company also puts up sterilized milk in 40-quart cans. The top of the can is closed with a patent lever, something on the principle

of a beer-bottle stopper lever. As these cans are filled while hot, they are also hermetically sealed. At the bottom of the can is an opening for the insertion of a faucet, which can be kept closed by a sterilized cap. When the milk is to be used, the can is turned upon the side and the faucet, previously carefully sterilized, inserted. The milk can be safely used from the can if proper care in cleaning the faucet has been observed. This milk is on sale at some of the booths in New York City, supplied by Straus. The milk, which the writer has had the opportunity of tasting at the factory, is very rich and most delicious, and without a particle of boiled or cooked flavor. As the cream and milk have been thoroughly mixed, it tastes more like pure cream.

At Danby, N. Y., there is also a plant for sterilizing milk in bulk, hot water being used instead of dry steam. The Appleberg method seems to give the most satisfactory results.

In Boston, in addition to the laboratory for sterilized milk, there is some work in the distribution of pasteurized milk from one of the church dispensaries. There is in that city a careful milk inspection, but no sterilized milk is sold in quantity, so far as I was able to learn from the milk inspector. In Brooklyn, also, there is a very careful chemical and veterinary milk inspection. The city is divided into districts, which are gone over carefully. It is required that the milk shall have 12 per cent solids and 3 per cent fat. In New York during the past summer less adulteration has been found than usual. In none of these cities, however, is especial attention paid to the milk supply with reference to city control of pasteurized or sterilized milk.

EFFECT OF STERILIZATION ON DIGESTIBILITY.

If the milk is heated to such a temperature that the albuminoids are coagulated, it loses its flavor and acquires a boiled taste, and is neither so digestible for children or adults, nor is it so attractive in appearance. When properly pasteurized or sterilized, however, the taste is not in any way impaired and it is quite as digestible as the raw milk.

To insure a thoroughly healthy supply, all the milk should be under the control of the State and city boards of health. This should include an inspection of the animals themselves, of the stalls, feeding, water supply, methods of milking and saving of the milk. Not only should the animals be perfectly healthy, but the stalls should also be kept thoroughly clean, well whitewashed, and from time to time disinfected by means of carbolic acid. The stalls should also be well ventilated and so situated that the sunlight will be admitted. Attention should be paid to the health of the attendants, and expectoration about the stalls should be prohibited. Only the best clean fodder should be used. In milking, care should be taken that the teats of the animals are clean, and the utmost neatness and cleanliness of hands and clothing should be observed on the part of the attendants about the stables. Instead of selecting particularly old and dirty clothing for the milking, only clean,

washable overalls should be used, and these should be kept exclusively for that purpose.

The water supply is often of as much importance as other precautions. There is no reason why the lower domestic animals should not be supplied with good water, and there are many reasons for believing that an impure supply is injurious. The necessity for pure water in the dairy is well illustrated by the following incident: In a certain dairy the utmost care was observed in cleaning and scalding the milk cans. However, just before the cans were filled, they would be rinsed with cold water from the well. This well was situated near the stalls, so that it received the drainings and washings from the manure, and while the well ordinarily, perhaps, was in good condition, it was at any time liable to contamination by typhoid fever and putrefactive bacteria. The simple rinsing of the cans was sufficient to destroy all the good effects of the previous care.

A company in Copenhagen, Denmark, and one in Stockholm, Sweden, pay considerable attention to securing a good milk supply, thus to some extent replacing the boiling of milk.

Although by the order of 1885 a person suffering from any dangerous disease, or who has recently been in contact with a person suffering from a dangerous disease, is prohibited from participating in the production, distribution, or storage of milk, in country districts this law can be easily evaded. The regulations of the two companies above named require—

(1) Veterinary control of all the animals on the farm and exclusion of the milk from unhealthy cows.

(2) Cooling of the milk by ice to 41° F. at the farms.

(3) Filtration of the whole milk through fine gravel.

(4) Absolute cleanliness of all the bottles and cans used.

The company has in its employ seven veterinarians, one of whom devotes his time to visiting the farms in rotation. Of course, where there are many animals it is difficult to inspect all at one visit, but each animal is examined carefully once a month. Special attention is given to the examination of the udder and adjacent glands. If a tuberculous cow is detected, it must be at once separated, or if the health of a cow appears bad, it must be withdrawn for a time. The farmer is bound to report any case of illness occurring in the interval of the veterinarian's visit, and to withhold the milk until he arrives. Stall feeding is prohibited, except in winter. Infectious or contagious disease in the employees must be at once reported, and the milk supply they have handled kept back. The greatest cleanliness in milking must be observed, and the milk, after being strained, is at once cooled to 41° F. by ice.

In winter the food consists of rape-seed oil cake, hay and straw, and brewers' grain, while anything that might give the milk an unpleasant taste, such as turnips, is excluded. This care and precaution on the

part of the farmer is secured by the company agreeing to pay a proportionately larger price for the milk, and even paying for the milk if it is not used. The carefully collected milk is tasted and sampled from every cow, and then filtered through gravel in perforated tin trays (fig. 62). In the lowest tray the gravel is the size of a split pea—in the highest, of a pin's head. Three thousand bottles are filled every evening, and the milk guaranteed for twenty-four hours. Cream may also be treated in the same way. Soda is used for cleaning the cans.

In addition to this filtration, the milk may be pasteurized. This is done by placing the bottles in racks in a long trough filled with water. A coil of steam pipe heats this water to 75°, when a contact thermometer rings a bell, the signal for shutting off the steam. The milk is then allowed to cool to 60° C., then taken out and put on ice. The company has daily analyses made, and these are published monthly.

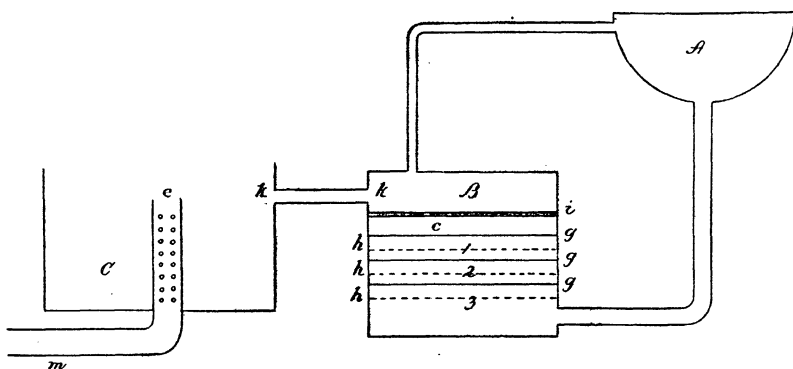


FIG. 62.—Milk filter. *A*, tank; *B*, filter; *C*, storage tank; 1, 2, 3, perforated metal trays to hold gravel; *g g g*, india-rubber rings to protect enamel; *h h h*, galvanized rings; *i*, 5-ply filter cloth of close texture, surmounted by 1-ply of fine texture; *k k*, pipe to carry off milk from the filter; *e*, perforated pipe, so as to draw milk from every part of the tank to the bottling room.

In Stockholm controlled and uncontrolled milk are sold. The company has built two large cow sheds. The walls, floors, and troughs are cemented; the buildings well lighted and ventilated. The cows are kept in sheds throughout the year. A number of men are employed in continually cleaning the animals and removing the refuse. There is no odor about the stalls, as this is all absorbed by the peat. Before milking, the floor is swept perfectly clean, the milkmaids must wash their hands, wear special aprons, and carefully clean the udders. The cans are washed with boiling water and the milk strained through muslin and fine copper gauze, and then cooled. A veterinary surgeon lives on the place, and the cows are always sold after a year or two, so as to keep fresh milkers all the time. The finest and healthiest cows are reserved for children's milk. By isolating the calves of tuberculous animals and feeding them on boiled milk Professor Bang has succeeded in keeping them free from disease, and has carried out a number of experiments on large estates. He also emphasizes the fact that small herds are rarely tuberculous.

DIFFERENT FORMS OF APPARATUS.

A great many different forms of apparatus for the pasteurization or sterilization of milk in bulk have been used abroad, and the description and figures of some of these, partly reproduced from Weigmann's report, are here given. Many are unnecessarily complicated. The simpler apparatus gives equally satisfactory results.

One of the first pasteurizers in bulk to be used was a continuous-working apparatus, and consisted of a double-walled copper cylinder,

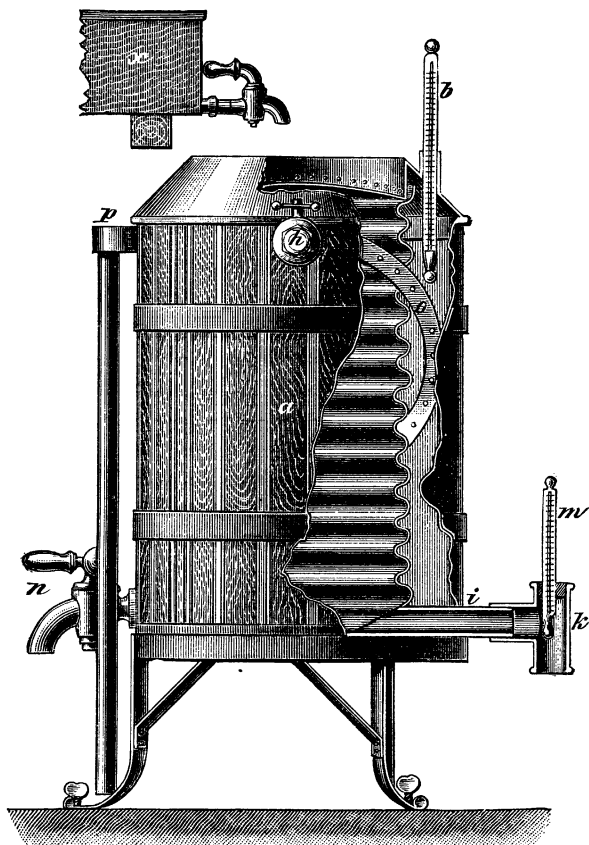


FIG. 63.—Thiel's pasteurizing apparatus.

which could be heated by steam. The form now used is practically unchanged. The milk flows in at the top, is kept thoroughly stirred by means of a crank at the bottom, and flows out from the side, near the top, at a temperature of 70° to 80° C. The stirring apparatus prevents the burning of the milk and also the separation of the casein.

In 1886 Thiel recommended the following apparatus (fig. 63): An outer sheet-lead mantle, lined with wood, *a*; an inner tinned corrugated copper cylinder, *b*, with a lid, *c*, which fits tightly over both. The water

used for heating enters through *h*, and circulates, by means of a pipe, in the space between the outer and inner cylinder, *p* serving as an escape pipe. The milk flowing over the corrugated sides is heated and escapes through *i* and *k* at a temperature which can be noted by a thermometer placed at *k*. The milk reaches a temperature of 60° C., and its taste and appearance are good. Experiments have shown that milk treated in this apparatus will keep two or three days longer than that which has not been pasteurized.

Another apparatus, Hochmuth's, is a combination of a warming, pasteurizing, and cooling machine (figs. 64, 65, 66, and 67). This may be constructed so as to be placed either in a vertical or a horizontal position. Pasteurization is accomplished by means of steam pipes, the steam circulating between the coils through which the milk flows. This apparatus, however, offers the objection that the milk is too easily burned on the coils and the apparatus is one difficult to keep clean.

Fjord's apparatus, already illustrated in figure 55, avoids these troubles. Some modified forms of this are seen in Ahlborn's apparatus (figs. 68 and 69).

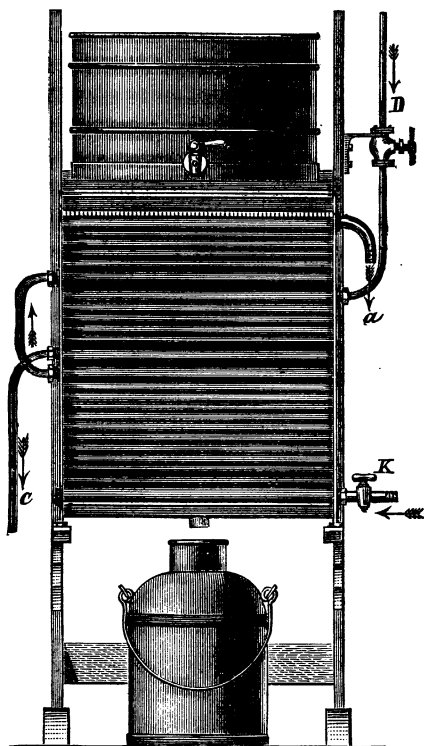


FIG. 64.—Hochmuth's pasteurizing apparatus.

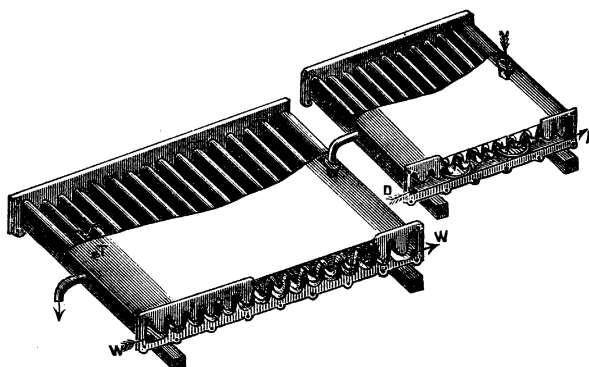


FIG. 65.—Section of Hochmuth's pasteurizing apparatus.

Another similar apparatus, made by the Bergedorfer Iron Works, shown in figure 70, differs from the others mainly in the way the milk

is introduced. The cold milk, in entering, is warmed by the volume of milk already pasteurized.

The apparatus shown in figure 71, constructed by Dierks & Möllman, in Osnabruck, is intended especially to prevent the burning of

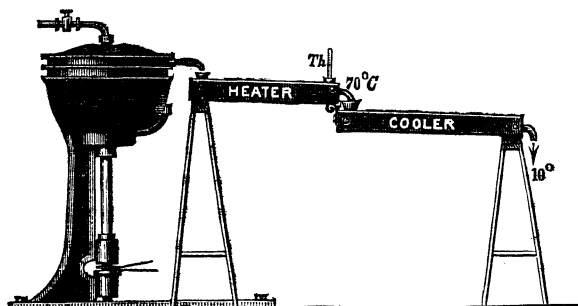


FIG. 66.—Hochmuth's pasteurizing apparatus, with parts arranged horizontally.

the milk. It consists of an outer box, lined with wood. Within this is a cylinder provided with a removable top, and within this a second cylinder which leaves between the two but a small space. The milk is forced mechanically through the space between these cylinders, and at the same time is heated by the steam surrounding the outer cylinder.

The burning of the milk is prevented by means of a stirrer provided with arms which make twenty-five to thirty revolutions per minute, and in every revolution they come in contact four times with each portion of the milk. In every minute each particle of milk is agitated one hundred and twenty times, thus entirely preventing the burning of the milk in contact with the cylinder and the deposition of albumin.

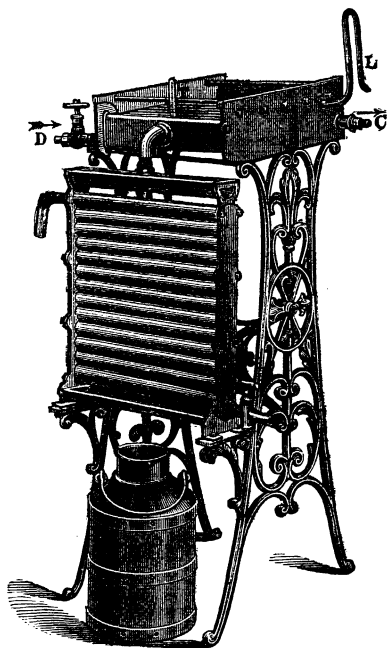


FIG. 67.—Hochmuth's compound pasteurizing apparatus.

Another more expensive apparatus, constructed by Lefeldt & Leutsch, in Schöningen, Germany, consists of a centrifugal which first frees the milk from impurities. As experiments have shown, it is really those bacteria which are ordinarily found in the dirt, particles of feces, hair, etc., which most easily resist heating, partly because they are mechanically protected by the dirt in which they are

found and partly because spores are often present. The removal of these mechanical impurities aids the subsequent pasteurization. Flowing from the centrifugal basket, the milk passes through a narrow

space about 1 inch in diameter, which is heated from the outside by direct steam. This apparatus has the advantage of being compact, utilizing the steam thoroughly, and preventing the milk from burning.

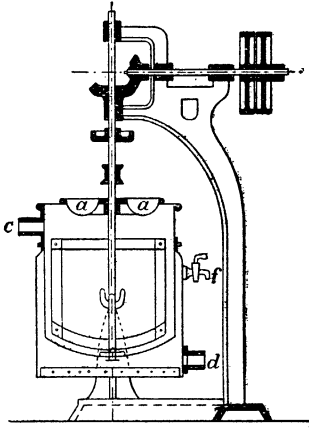


FIG. 68.—Ahlborn's pasteurizing apparatus.

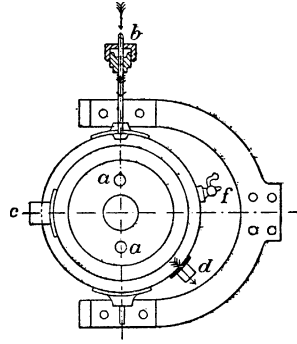


FIG. 69.—Ahlborn's pasteurizing apparatus—modified form.

Five hundred liters (125 gallons) per hour can be pasteurized with this machine at a temperature of 70° to 75° C. (fig. 72).

The many forms of apparatus recommended for the continuous pasteurization of milk indicate that there are always some difficulties, and

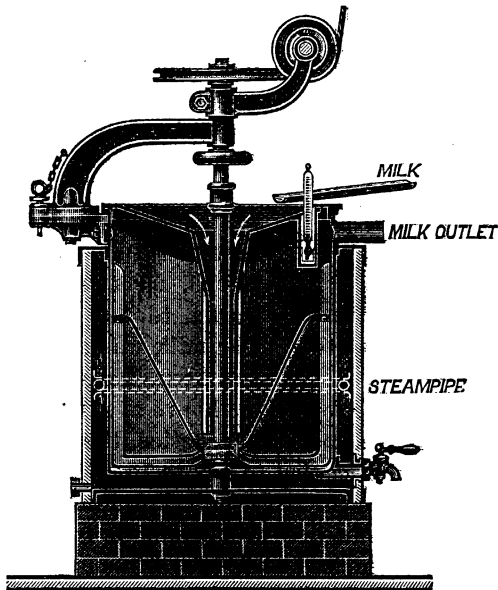


FIG. 70.—Ahren's pasteurizing apparatus.

that the results obtained are not satisfactory. The burning of the milk on the sides of the apparatus, and consequent uneven heating of the remainder, and the temperature used, 70° to 75° C., which ordi-

narily will cause precipitation of some of the casein as well as impart to the milk a burned flavor, are objectionable. To avoid this, Bitter has constructed an apparatus which does not permit of a continuous pasteurization, as in the other described apparatus, but which allows of a longer heating of the milk. In the case of a number of bacteria, especially the tuberculosis bacillus, a temperature of 68° C. for fifteen minutes is sufficient to kill. For certainty, the milk should in all instances be exposed to this temperature for thirty-five minutes. Bitter found, further, that when the milk was heated to 68° for thirty-five minutes, and then cooled to a temperature of 15° C., it would keep fifty to seventy hours longer than that which was not pasteurized. This temperature, when maintained for thirty-five minutes, appeared from

his experiments, performed with 40 liters of milk, to be sufficient for the full pasteurization of the milk. Unskimmed milk may be heated for fifteen minutes to 75° C. without any coagulation or burning or any material change in the flavor taking place. This milk, when cooled to 16° C. and saved for sixty hours, did not keep any better than the milk heated for thirty minutes to 68° C.

It is of course easily understood that the milk keeps better after pasteurization the more it has been cooled. To demonstrate the keeping properties under the conditions which would actually obtain in practice, Bitter exposed milk which had been heated to a temperature of 75° C., first to 14° C. for ten hours, then to 23° C. for twenty-two hours, afterwards to 30° C. for seven hours. The milk was still good and kept for five hours longer at 23° C. The milk

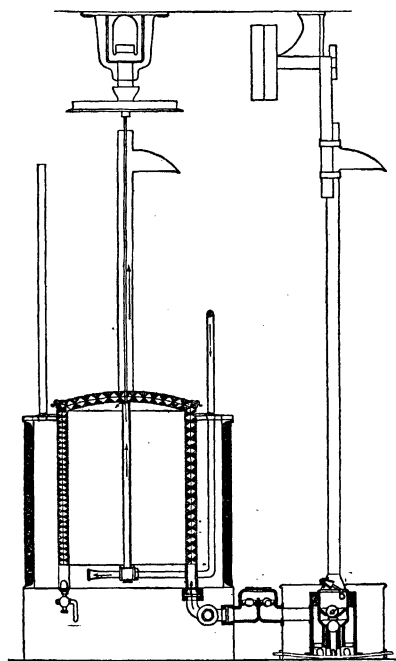


FIG. 71.—Dierks & Möllman's pasteurizing apparatus.

was consequently kept for forty-four hours at a temperature not at all calculated for its preservation. In practice, the milk, before it is sent out from the creamery, is cooled to 10° to 15° C. and then distributed from large cans of 40 liters capacity, and the quantity of the milk, therefore, has considerable influence in keeping it at a low temperature. Milk that has been pasteurized at 75° for fifteen minutes, or 68° C. for 35 minutes, and then cooled, will keep in the warmest summer for thirty hours. If the temperature of the air is lower, the milk will keep longer. Milk heated to 75° C. will keep at a temperature of 18° to 20° C. for sixty-six hours, and at 14° to 16° C. for three days. This milk was

in perfect condition for sale; there was no coagulation or unnatural taste, and its availability for the manufacture of butter was not in any way injured.

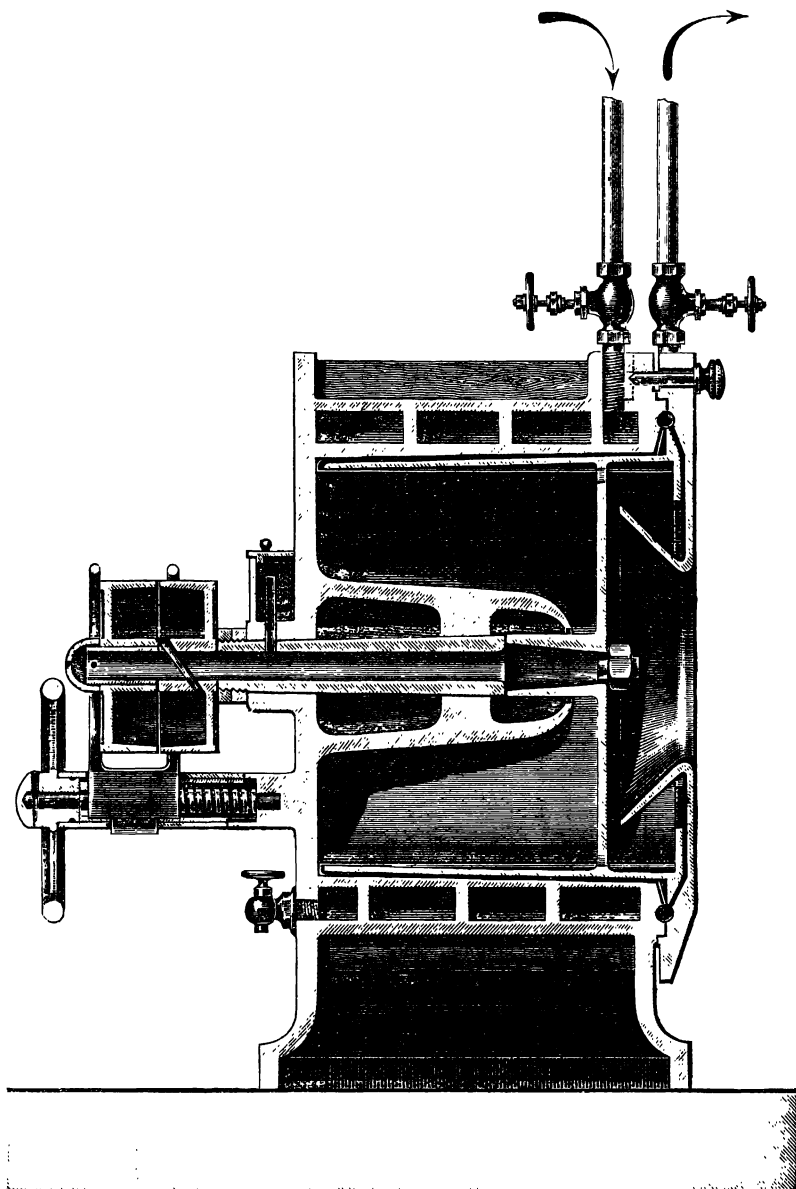


FIG. 72.—Pasteurizing apparatus, constructed by Lefeldt & Leusch.

The apparatus which Bitter recommends for pasteurization is shown in figure 73.

A tinned copper cylinder, with cap which fits tightly, serves as a receptacle for the milk. About 1 inch from the inner side of this

vessel is a coil of tinned copper pipe which runs to the bottom of the cylinder and then back to the top, the inner coil being narrower than the outer, and from the top of this second coil the pipe returns to the bottom of the cylinder. Through this long coil steam is passed. The milk is kept stirred by an arrangement of paddles which can be readily understood from figure 73. It is very important that the entire pasteurizer and the cans shall be kept thoroughly cleaned. From this pas-

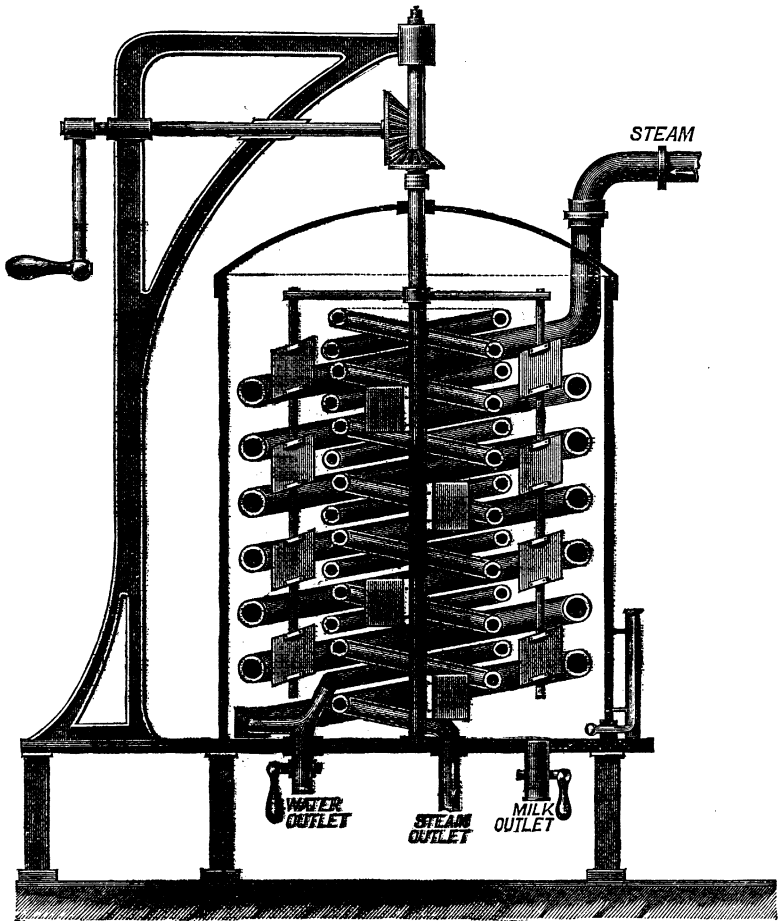


FIG. 73.—Pasteurizing apparatus—after Bitter.

teurizer the milk is allowed to pass through a cooler, as seen in figure 74. This is always thoroughly cleansed and then exposed for a short time to the action of steam. If the hot milk is very quickly cooled, its keeping properties are increased, as any bacteria which might still be present are either killed or so weakened by the sudden change of temperature that a long time would be required before they could again multiply.

STERILIZATION OF MILK.

As already noted, while the temperature of pasteurization, 65° to 70° , is sufficient to kill all disease-producing bacteria, there are a number of germs which are not affected by this temperature, especially the spores, and some which even multiply readily at 70° C. While these latter are not apt to be present in the milk, they may come from the water or dust of the air. The temperature necessary to totally destroy all of these is often over 100° C. (for example, *Bacillus subtilis*), and it must be maintained for a considerable time. This temperature would necessarily injure the taste and appearance of the milk. In laboratory practice it is possible to obtain a thorough sterilization by an interrupted heating. If the milk is heated one to two hours at a time each day for five to six

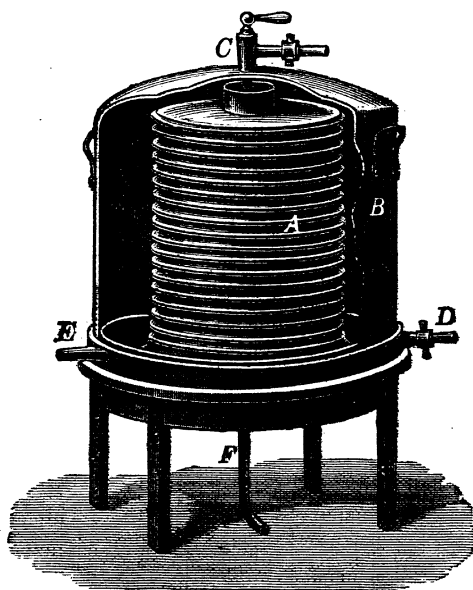


FIG. 74.—Milk cooler—by Schmidt, in Bretten.

days consecutively at 75° C., the destruction of spores, which in the meantime would have developed, can be accomplished. In practice, however, this process would be too expensive and too troublesome. A modification of this process consists in heating the milk in closed flasks to a high temperature (above the boiling point of water).

The thorough sterilization of milk is, therefore, not very practical, but one or two methods and apparatus may be described. In the Neuhauss-Gronwald-Oehlmann sterilization apparatus (fig. 75) the milk is heated first to 85° to 90° C., and then a second time to 102° C. The bottles must be well blown and annealed, free from alkali, and very carefully cleaned. This is accomplished by boiling with soda, then with water, and finally by sterilizing in large boxes at 100° . The bot-

tles are closed with a patent stopper, like the beer-bottle stoppers, and these must be carefully sterilized before use, using only those with the best rubber rings. After sterilization the flasks are carefully filled with the milk, the hands being first very thoroughly washed and all antiseptic precautions observed. The milk is then heated for half an hour at 85° to 90° C., and the flasks are gradually cooled, being allowed to remain in the sterilizer. They are on the same day submitted to a second heating of 102° to 103° C. The apparatus consists of a double-walled box, made of tinned copper plates. The lower portion, *a*, is fixed; the top, *b*, movable and counterbalanced by weights; the top fits over the lower basket steam tight; *c* is a thermometer, and *d* an escape steam

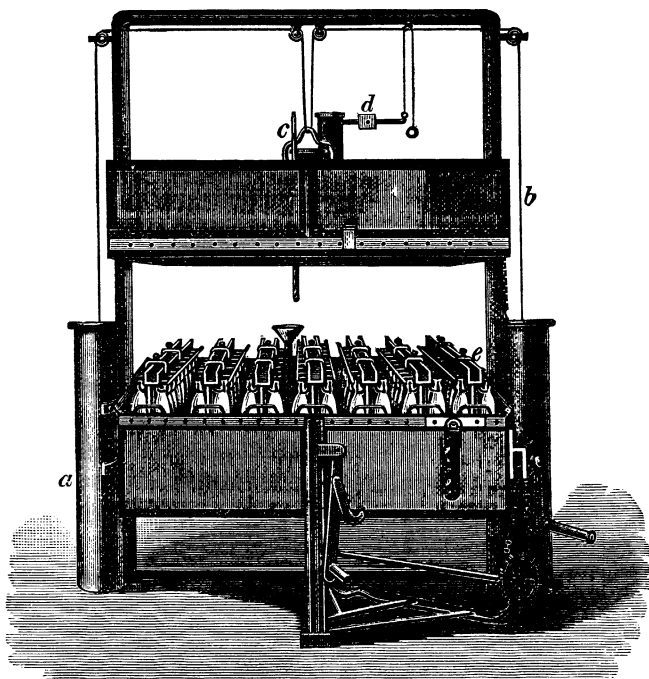


FIG. 75.—Sterilizing apparatus, by Neuhauss-Gronwald-Oehlmann.

valve which can be set at any desired pressure. The flasks are placed in special trays which can be easily moved, and between the rows of flasks are levers which serve to close the patent stoppers. The thermometer dips into one of the flasks and indicates the temperature of the milk. When the apparatus is closed, the steam, under pressure of $1\frac{1}{2}$ atmospheres, is allowed to enter slowly until the air is driven out. It is important that the apparatus shall not be entirely closed until the air is entirely driven out. When the temperature has reached 100° C., more steam is turned on, the pressure gauge having been set for 102° to 103° C. In a short time the flasks will have reached a temperature of 100° C., and they are then kept at this temperature for thirty min-

utes. A few minutes before the end of the sterilization the pressure valve is opened, thus permitting the milk in the flasks to boil up, and any gases which might still be present in the milk are driven out. The result is that the closed flasks of milk, when cold, no longer contain any air, as in the upper part of the flask there is a vacuum, consequently aerobic bacteria could not multiply. The flasks are now allowed to cool slowly to 50° to 60° C., then placed in warm water to prevent cracking. Cold water is gradually allowed to mix with this, and the flasks are finally preserved on ice. The purer and fresher the condition of the milk, the more satisfactory are the results obtained. In this connection, if milk is to be used for thorough sterilization, special care should be taken to see that the milk is not unnecessarily exposed to contamination by such bacteria as are difficult to kill and are apt to get into the milk from dirt, old straw, and bedding. In addition, cans, bottles, and receptacles must all be kept perfectly clean.

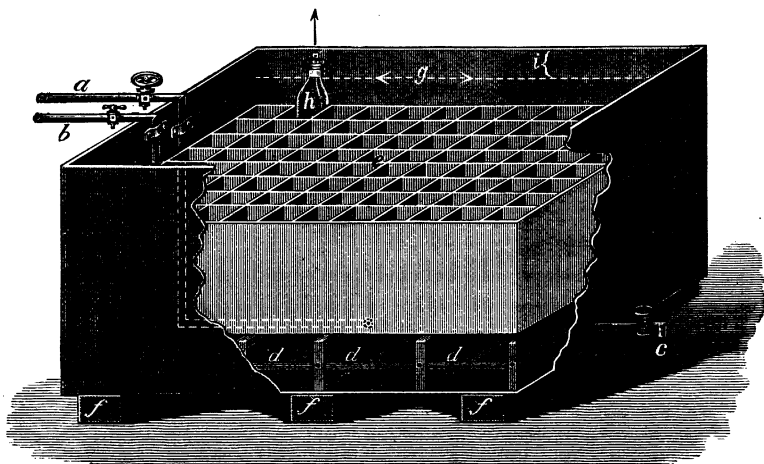


FIG. 76.—Milk-sterilizing apparatus—after Paul Ritter von Hamm.

In practice, it makes a difference whether the sterilization is conducted with heated water or with steam, whether the steam is mixed with air, is moist or dry. Although the process above described is usually satisfactory, yet a complete sterilization does not always result. It has been found, too, that almost equally satisfactory results are secured by heating to 102° to 103° C. for three-fourths to one hour, without any previous sterilization.

The Soxhlet apparatus, originally intended for household use in sterilizing milk, has been utilized, with slight modifications, for sterilizing the milk in quantity (fig. 76). This is intended for 94 flasks of 1 liter (1 quart) capacity, or, instead of the flasks, cans with patent air-tight covers may be used. The apparatus is simple in construction. *a* serves for the admission of steam, *b* for the admission of water, and *c* is the outlet tube. The bottle holder, *e*, is made of wood, and rests on metal bars. The holder is filled with water to *g*, and the flasks are filled with

milk to *h*, and placed in the box. The stoppers are the ordinary beer-bottle stoppers, and are loosely placed in the mouths of the bottles. Steam is then turned on until the temperature, shown by the thermometer that passes through the cover of the whole box, reaches 110° . This requires about one hour, and the flasks are kept at this temperature for fifteen minutes. The milk fills the bottles entirely and a little runs out from the mouths. When the steam is turned off and cold water is introduced to reduce the temperature of the flasks to 50° C., the contraction of the milk draws the corks down tightly on the bottles, and the wire clamp can then be readily fastened.

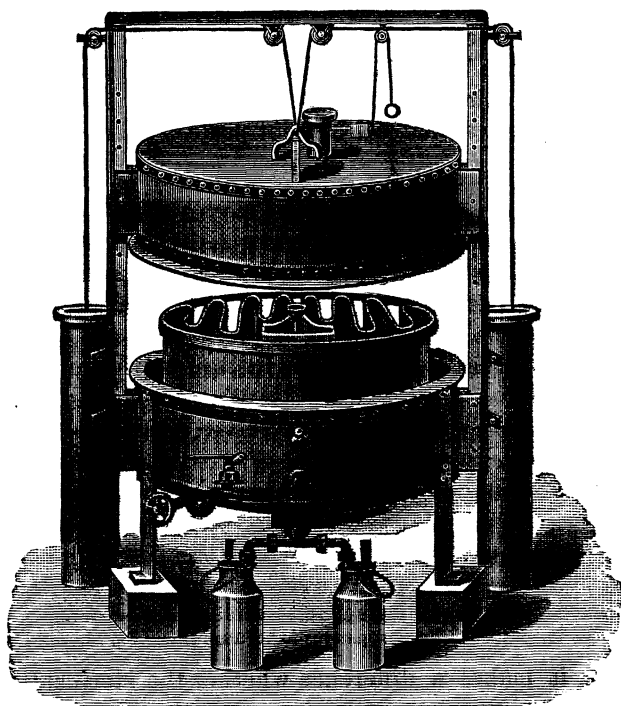


FIG. 77.—Bottling sterilizing apparatus.

A number of creameries have begun the process of shipping sterilized milk in cans of 10 to 12 liters capacity. An apparatus adapted to this purpose is shown in figure 77. The milk flows through a trough arranged in folds, so that a large surface is exposed to the action of the steam, and passes directly through sterile tubes into cans.

In addition to the sterilizing apparatus already described, the following (fig. 78, *b*) may be used: An ordinary fruit jar may have an opening cut through the top of the cover, provided with a shoulder and lid that will screw down. Through this opening an agitating rod or wire may be passed to keep the milk thoroughly stirred up while it is being heated. This can then be removed after heating, and the opening is then closed while the flask is still hot; or this opening may have a stiff cotton plug.

Another arrangement which will answer the purpose for sterilizing milk in quantity may also be used. A double-walled rectangular box, made of copper or tin (fig. 79), may be arranged so that the milk can be heated to any desired temperature. This can be stirred during the proc-

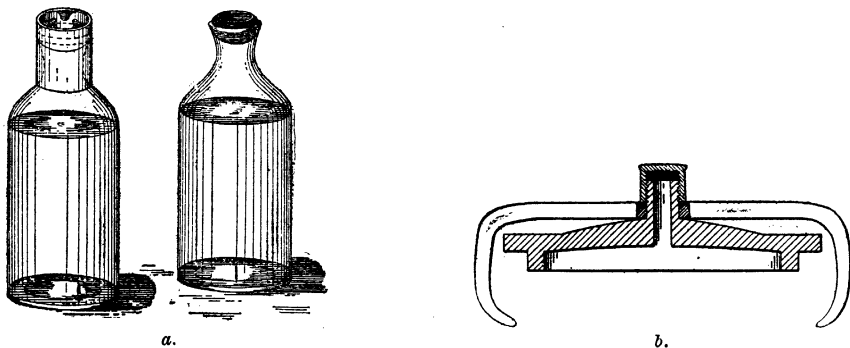


FIG. 78.—*a*, Soxhlet's patent sterilizing bottles and top; *b*, top for fruit jar for sterilization.

ess and the milk at the same time sterilized. Any loss or change in the taste of the milk is detrimental when it is to be used for food. The thorough stirring of the mass keeps it evenly heated throughout, so

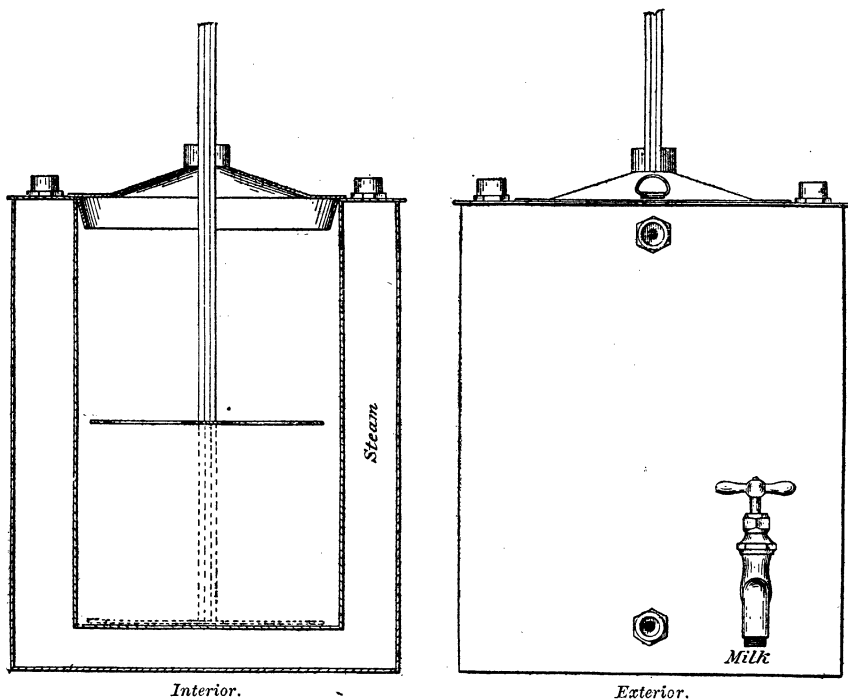


FIG. 79.—Sterilizing box.

that there will be no charring or scorching of any milk or any adhering to the sides of the vessel. A series of these rectangular boxes might be provided, connected with each other by pipes and stopcocks. From these sterilizers the milk may be filled into sterilized bottles, or into

large sterile cans, which can be hermetically sealed. To save expense, the outside of this double-walled box might be made of wood, or, better, of sheet iron, and the whole then incased in a wooden box to retain the heat.

The flasks or other vessels in which the milk is stored should, after cooling to about 60° C., be placed in water and thoroughly cooled.

The proper cooling of the milk and placing in clean bottles or cans is absolutely necessary for securing the full effect and purposes of pasteurization or sterilization.

The methods and apparatus which have been described are all adapted for the pasteurization or sterilization of milk. While some will appear too complicated and expensive to be adopted or copied, others will be found well suited, or modifications and improvements will easily suggest themselves.

That a uniform and cleanly milk supply can be obtained only when the State or town undertakes official control and inspection of animals has already been indicated. Where this is lacking, the consumer and the public generally may protect themselves in a great measure from disease by adopting any of the methods above indicated, either in the household or in the creameries. For these processes to be successful, the utmost cleanliness of vessels and manipulation must be observed; the milk must be clean, well-strained and aerated, the pasteurization or sterilization systematically conducted, the milk filled into bottles and cans while hot, and these latter then cooled before distribution. The pasteurized or sterilized milk should be distributed in unbroken packages only, and these should be no larger than would be used in twenty-four hours. If distributed in large vessels, these should be hermetically sealed to avoid all contamination. Probably the cheapest vessel, and the one most easily obtained for sterilization in small lots, is the ordinary patent-stoppered beer bottle; for handling in larger quantities, milk cans with hermetically sealed tops.

The apparatus for continuous sterilization does not give as satisfactory results as when an interrupted process is adopted.

By the use of properly pasteurized or sterilized milk, therefore, not only should the spread of disease be lessened, but also the health of milk consumers in general should be improved.

The use of pasteurized or sterilized milk prepared in bulk can, however, only be carried out to the best advantage when it is undertaken with the object, not of making money by supplying a material which will barely pass inspection, but of furnishing an article collected and prepared with all possible precautions, where all means have been adopted to provide against mistakes or carelessness.

The simpler forms of apparatus described can be easily and cheaply manufactured by any good tinner or coppersmith, and many slight modifications and improvements will suggest themselves in practice.